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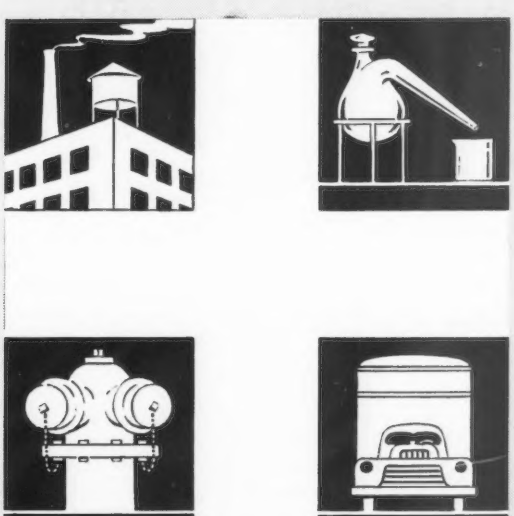

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WE WANT to call attention to the addition, on our masthead, of the name of Thad Hackett, prominent free lance artist responsible for the high quality of design which has characterized our fledgling Journal since its birth. We hope Mr. Hackett's talented art direction will be a permanent part of the Journal's continuing growth... Last issue on our inside back cover we printed the Safety Engineers' Creed in a design suitable for framing. Response was so favorable that this issue we are presenting, in a like manner on that page, the Canons of Ethics for Engineers. Perhaps you will find these two fine codes of conduct appropriate for display in your office... Also in this issue... Nobel prize-winning geneticist Hermann J. Muller has written a thought-provoking article on "After Effects of Nuclear Radiation," which asks for reexamination of the exposure limits now considered "safe" for workers in industries using radioactive material... The University of California's J. H. Mathewson and Robert Brenner take a new look at quality control applied to accident statistics.

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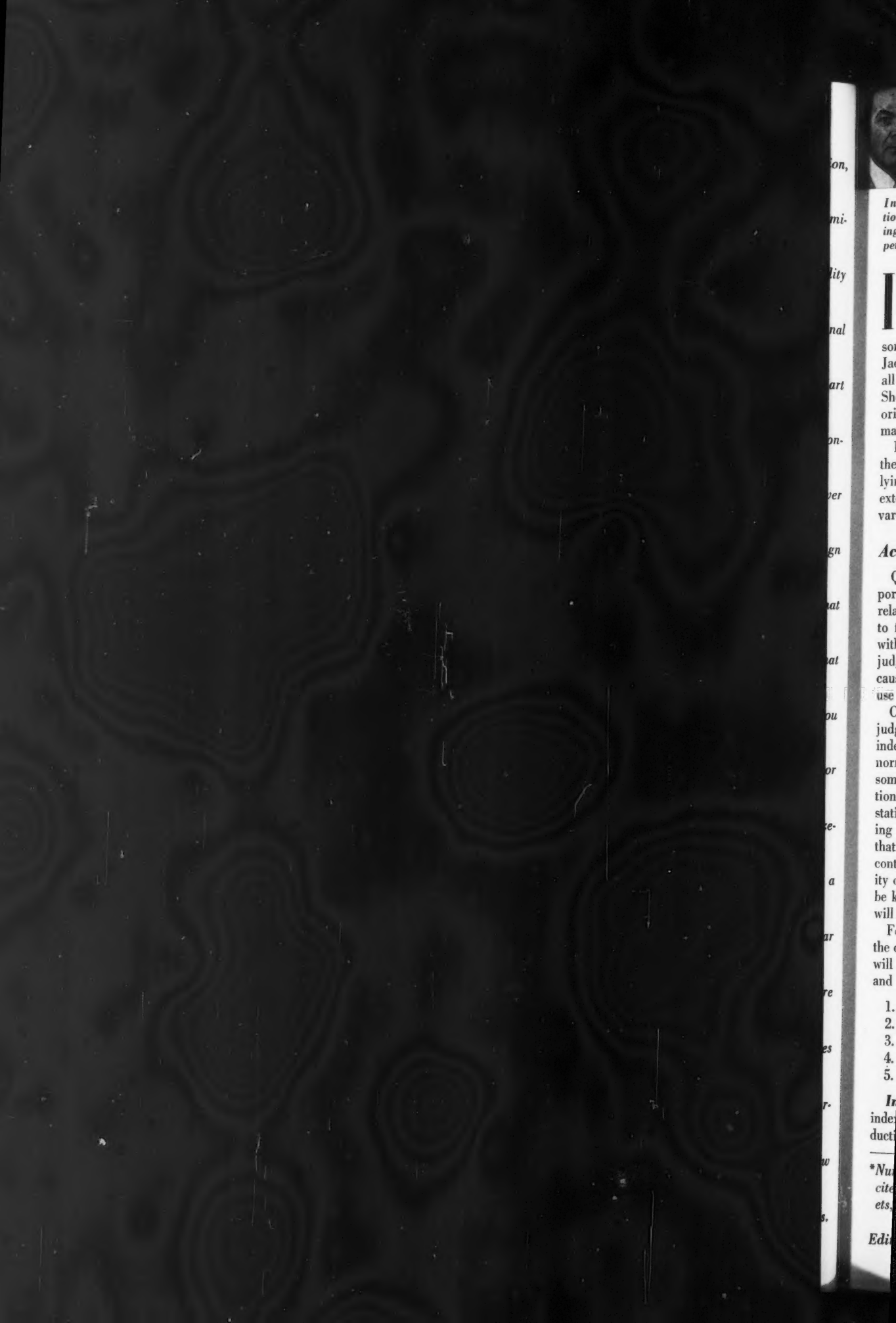

Professor J. H. Mathewson is assistant director of UCLA's Institute of Transportation and Traffic Engineering and author of many papers on safety research.

Analysis of ACCIDENT STATISTICS

by J. H. Mathewson and Robert Brenner

Robert Brenner is associate engineer-statistician, UCLA, where he is teaching, doing research and working on a Ph.D. in industrial safety and engineering statistics.

INTRODUCTION: The importance of a statistical approach in the control of accidents has been reported by several authors including Goode (1), Howell and Johnson (2), MacFarland (3), Mathewson, Brenner and Hulbert (4), Nordan, Orlansky and Jacobs (5), and Lee (6)*. The techniques reported by all of the above writers essentially are adaptations of the Shewhart Quality Control Chart techniques which were originally designed to assist in controlling the quality of manufactured product (7).

In this paper, the authors have as their first objective the presentations of some of the statistical theory underlying the various techniques. The second objective is to extend the techniques to situations where there are wide variations both in severity and amount of exposure.

Accident Control Chart Techniques

Quality control charts are graphical techniques which portray the actual quality of the manufactured product relative to the range within which the quality is expected to fluctuate due solely to random causes. Concomitant with the event of quality falling outside the range is the judgment that some non-random, hence assignable, factor caused this event to transpire. A complete discussion of use of these charts is given by Grant (8) and Burr (9).

Control charts as applied to safety work facilitate the judgment that an accident rate (or any other convenient index of accident likelihood) has deviated so far from its normally expected value that it is highly probable that some new, non-random causality has come into operation. Although the control charts for analyzing accident statistics are logically identical to charts used for analyzing quality of manufactured product, the writers believe that these charts should not be referred to as "quality control charts." It is accordingly recommended that quality control charts when employed in the accident context be known as "accident control charts." This expression will be used in this paper.

For purposes of this paper, the authors have organized the control chart technique into five basic elements which will first be discussed in context of quality applications, and then in the safety context. These elements are:

1. Selecting the quality index.
2. Estimating the range of variation of the index.
3. Initial setting up of charts.
4. Judging as to assignable causation.
5. Revising charts to reflect changing conditions.

Index of Quality: Any of a number of different indexes may be taken to represent the quality of production but careful judgment has to be exercised as to the most appropriate index for a given situation. One is the number of defective items produced during a given period of production time; another is the number of defective items produced in a given production lot. Control charts using the former as the index of quality are referred to as "C" charts, while those using the latter are referred to as "$\bar{C}$" charts.

Various measures of accident likelihood (the analog in accident control charts of the index of manufactured quality in quality control charts) have been reported. Goode (1) treats number of accidents occurring in some period of time; MacFarland's example utilizes the number of first aid cases per thousand man hours worked (3), Mathewson et al (4) consider the number of motor vehicle accidents per 100,000 miles of driving; Lee (6) uses the number of major and minor injuries per 100,000 man hours worked. All of these indexes can be classified into one of two categories—first, the raw number of accidents occurring in some period of time and second, the number of accidents† occurring per unit of exposure.

A complete discussion of the probability models underlying the use of each of these measures as the index of accident likelihood in accident control charts is given in an earlier work by the authors (4). In this paper it will suffice to say that the control charts are based upon the generally accepted belief that the random variables Y_t (raw number of accidents occurring during time t) and R_t (the frequency rate during period t) have the Poisson distribution with standard deviations $\sqrt{Y_t}$ and $\sqrt{R_t}$ respectively (10) (11) (12) (13) (14). This is expressed in the following probability statements:

"Y" CHART—RAW NUMBER OF ACCIDENTS

$$\Pr\{ Y' - A\sqrt{Y'} < Y_t < (Y' + A\sqrt{Y'}) \} = f(A) \quad [1]$$

"R" CHART—ACCIDENT RATE

$$\Pr\{ (R' - A\sqrt{\frac{R'}{E_t}}) < R_t < (R' + A\sqrt{\frac{R'}{E_t}}) \} = f(A) \quad [2]$$

where:

Y_t = number of disabling injuries occurring in month t

E_t = exposure in month t expressed in units of 1,000,000 man hours

R_t = actual frequency rate in month t = $\frac{Y_t}{E_t}$

Y' = some standard number of accidents in a month to which Y_t would be compared

R' = some standard frequency rate to which R_t would be compared.

**Numbers in parentheses, ( ), identify references that are cited at the end of the paper; numbers in square brackets, [ ], refer to equations cited in the text.*

†The term "accident" is used here to describe a discrete event which can be either injury producing or non-injury producing. Hence all indexes utilizing severity of injury are eliminated.

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Statement [1] tells us that the range in which the raw number of disabling injuries in any month should fall is centered around the standard Y′ and extends to A standard deviations (of Y′) in both directions from Y′. The standard is the number of accidents occurring in a month under "normal" conditions. In some proportion f(A) of successive months, the number of accidents would be expected to fall in the range defined by A standard deviations in each direction from the standard. Similarly, [2] defines the range in which the rate should fall as A standard deviations (of R′) around R′. Criteria for deciding how large A should be will be discussed shortly. At this time let us first consider criteria for determining whether the "Y" chart (raw number of accidents) or the "R" chart (accident rate) should be used, and second, what should be defined as the comparison standards Y′ and R′ in [1] and [2] respectively.

The decision as to whether a "Y" or "R" chart should be used depends directly upon whether or not exposure is changing. As long as exposure is not changing, analyses utilizing either index are logically equivalent. But where exposure is changing the rate index must be used. Expression [2] demonstrates that the range of variation for a rate is an inverse function of the square root of the amount of exposure over which the rate was computed. Thus, as exposure increases, the range of variation around the standard decreases. This explains the well known fact that accident rates of large companies do not fluctuate as much from month to month as do rates of smaller companies.

The comparison standards (Y′ and R′) may be defined in any of a number of ways but, in the main, they fall into two general categories. First, they can be defined as some function of a company's own previous accident record. Examples would be a company's (or department's) accident record of the previous month, of the same month of the previous year or of the average of the preceding six month experience, etc. Second, the standard can be some general average deduced from industry wide averages, National Safety Council figures or Bureau of Labor Statistics data. Both types of standards have their individual advantages. Where there are widely differing hazards among departments of a company, it is meaningful to compare a department against itself, but not against other departments. On the other hand, by comparing a rate with a national average it is possible to effect company-to-company comparisons. Therefore, a complete accident control chart program can effectively utilize both types. The sole requirement is that the index of accident likelihood for a given period and its comparison standard be expressed in the same units.

Range of Variation: When some monthly (or other time period) value of the index falls outside its control limits, the decision is made that it would be worthwhile to look for an assignable cause for the unusual deviation. If the value falls within the limits, the decision is that it is not worthwhile to look for an assignable cause. Either decision may be right or wrong, depending upon whether or not an assignable cause in fact exists. Inherent in these decisions are two types of possible error that are shown schematically in Figure 1. The first (Type I) is the decision to look for an assignable cause when there is none in actuality. The second (Type II) is the decision *not* to look for an assignable cause when in fact an assignable cause *is* present. The range of variation is selected so as to strike a balance between the consequences of these possible errors and of their relative probabilities. If the Type II error is more serious than the Type I error, a narrower range is indicated. If the Type I error is more serious, the range should be wider.

The control limits are set up in [1] and [2] at "A" standard deviation from the comparison standard. For example, when A=3 the implication is that 99.7 per cent of values of Y_t drawn from a population of mean Y′ will fall in the range of $(Y' \pm 3\sqrt{Y'})$, and 0.3 per cent will fall outside. When a value of Y_t falls outside of this range, two conclusions are possible. The first is that the accident likelihood as measured by Y_t is the same as that measured by Y′ and that a rare event (three chances out of 1000) has occurred. The second, refusing to concede that the rare event has occurred, asserts that the accident likelihood is not that measured by Y′ but in fact is either greater or less depending upon whether Y_t was beyond $(Y' + 3\sqrt{Y'})$ or $(Y' - 3\sqrt{Y'})$ respectively. Out of 1000 such decisions, three will be wrong; that is, accident likelihood will not have changed in three out of the 1000 instances, but will be erroneously stated as having changed. This is the so-called alpha or Type I error described above.

On the other hand, if a value Y_t falls within the range $(Y' \pm 3\sqrt{Y'})$ the conclusion would be that the accident likelihood is the same as that measured by Y′. This conclusion would be wrong if, in fact, the accident likelihood were different. The probability of an erroneous conclusion of this type (Type II error) is determined by Y_t and Y′.

As the decision range centered on the standard is increased, the probability of making the Type I error (concluding that accident likelihood changed when it did not change) is decreased. At the same time, the chance of failing to detect a change is increased. Decreasing the range will increase the chance of concluding that there was a change when in fact there was none. The decision as to size of range must be conditioned, therefore, by a prior judgment as to which error is more costly, failure to sound an alarm when an alarm should be sounded or sounding an alarm when no alarm should have been sounded. Wide ranges will rarely permit a false alarm but at the same time will frequently fail to sound a needed alarm. Narrower ranges frequently will permit a false alarm but rarely will fail to sound a needed alarm.

In setting up the original quality control charts, Shewhart's objectives, in part, were to set the limits (i.e., range of variation) so as to strike an economic balance between the probability of failing to detect an assignable cause for variation and the probability of looking for an assignable cause when one does not exist. In accident control charts, on the other hand, it is difficult to evaluate which error is more costly to industry. Repeated false alarms will soon condition operating personnel to receiving frequent reprimands so that when a real change in accident likelihood occurs, the necessary reprimand will have limited effect. Or if a safety director frequently reports to management that the accident rate is unusually

high, management will soon (consciously or sub-consciously) begin to ignore the reports. On the other hand, failure to detect early that accident likelihood has increased will result in delaying remedial measures and thus will allow more accidents, and losses, to occur.

Opinions vary as to what the allowable range of variation should be in accident control charts. MacFarland (3) utilizes 3 sigma limits in the rate chart. Goode (1) utilizes a range of approximately ± 2 sigma on a chart developed around raw numbers of accidents. Howell and Johnson (2) utilize 2 sigma limits in a rate-type chart. Norden (5) uses 2.576 sigma and makes certain statistical corrections*. It seems some compromise is indicated between 2 and 3 sigma limits.

The authors believe that two sets of limits can effectively be used in accident control charts, one set serving as warning limits and the other set as action limits. An accident rate falling beyond the warning limits but not beyond the action limits would be construed as evidence, although suspect, that there was a change in accident likelihood. A rate falling beyond the action limits would be interpreted as evidence of a change that no longer is merely suspect. There would be little chance of there not being a warning notice when in fact there was a change in accident likelihood. A complete discussion of warning and action ranges is given by Grant (8). One graphical scheme for utilization is shown in Figure 2.

Setting Up Charts: One of the immediate problems in setting up a control chart is to arrive at some value for the comparison standard. This presents no problem in quality control applications where the machine is set to produce at some predetermined quality level. Similarly, there is no problem in accident control charts where the standard is some known average such as a National Safety Council three year average. A problem does arise however, where the standard is some function of a company's own past experience. This problem relates to the number of points that should be used in the initial computation of limits in setting up a chart. Grant points out that, on statistical grounds, at least 25 points should be used, but that smaller numbers (8 to 10) may be used if lengthy time intervals must elapse before 25 points can be accumulated. Since it would be impractical to wait 25 months before setting up a system, a smaller number should be used. MacFarland uses for his example a 13 point base period that was developed on a weekly basis. The authors believe this 13 point base to be adequate since procedures for revising the limits, when applied, will correct any erroneous initial judgment.

The procedure essentially involves computing a set of "trial" action limits from the data in some base period. The data in the base period are then compared to these trial limits. If an index for a given month in the base period falls outside the trial limit, a new set of limits is computed excluding that index. This procedure will be demonstrated in an example later.

Figure 1
Possible Decisions and Errors in Interpreting Accident Control Charts

LOCATION OF POINT	DECISION	ACTUAL OPERATING CONDITIONS	
		An Assignable Cause of Variation Is Present	There Is No Assignable Cause of Variation
Point is above upper control limit.	Look for assignable cause.	Decision is correct.	Decision is wrong. Type I Error
Point is between upper and lower limits.	Do not look for assignable cause.	Decision is wrong. Type II Error	Decision is correct.
Point is below lower control limit.	Look for assignable cause.	Decision is correct.	Decision is wrong. Type I Error

Judgment of Assignable Causation: The control chart technique, specifically the limit settings, have as their ultimate purpose the facilitation of the judgment as to the probable presence or absence of an assignable cause for deviation from the expected value. Guiding principles are readily stated for interpreting quality from the value the index takes on during any period in relation to the control limits. But the control limits are themselves probabilistic criteria so that any guiding principles for judgment cannot supplant the judgment itself; that is to say, the guiding principles must be treated as guides and not as ironclad rules. In practice there are no hard and fast rules for deciding that action is indicated; consequently, each case must be carefully studied. The following criteria related to mathematical theory of extreme runs may be used as guides in interpreting control charts.

1. Action is indicated when there occurs a run of four or more points up (or down) that culminates in a point beyond the action limit, i.e., when each succeeding value is greater (or smaller) than the previous one and the last point in the run exceeds the action limit (MacFarland).
2. Where 2 and 3 sigma limits are used, action is indicated when the following number of points fall beyond the same (upper or lower) 2 sigma limit (Grant):
   a. Two successive points.
   b. Two out of three successive points.
   c. Three out of seven successive points.
   d. Four out of ten successive points.

**The limits utilized by Norden, Orlansky and Jacobs (5) are (changing their nomenclature to agree with that of this paper)* $R' \pm 2.576 \sqrt{\frac{R'}{E} + \frac{0.829}{E} \pm \frac{1}{2E}}$ *The third and fourth terms of this expression are corrections for continuity and the assumption of normality. The authors in this paper have chosen to omit these corrections in the interest of simplicity. The effect is to narrow the confidence interval and hence yield a less conservative judgment. However, the decrement in the sensitivity of the decision function is not considered to outweigh the gain in simplicity of computation.*

Figure 2
Schematic Representation of Accident Control Chart Showing Action and Warning Limits

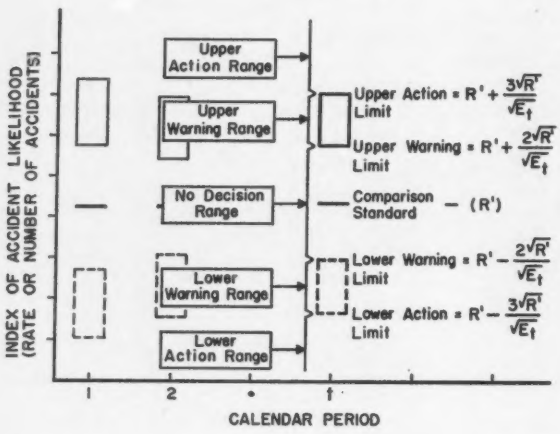

INDEX OF ACCIDENT LIKELIHOOD (RATE OR NUMBER OF ACCIDENTS)
Upper Action Range
Upper Warning Range
No Decision Range
Lower Warning Range
Lower Action Range
Upper Action Limit = $R' + \frac{3\sqrt{R'}}{\sqrt{E_t}}$
Upper Warning Limit = $R' + \frac{2\sqrt{R'}}{\sqrt{E_t}}$
Comparison Standard — (R')
Lower Warning Limit = $R' - \frac{2\sqrt{R'}}{\sqrt{E_t}}$
Lower Action Limit = $R' - \frac{3\sqrt{R'}}{\sqrt{E_t}}$
1
2
CALENDAR PERIOD

Figure 3
Accident Data for a Hypothetical Group of Companies

Month	Number of Disabling Injuries	Exposure Man-Hours x 100,000	Rate Dis. Inj./ 100,000 Hrs.
January, '53	27	25.4	1.06
February	48	26.6	1.80
March	80	32.7	2.45
April	58	35.7	1.62
May	64	37.4	1.71
June	72	38.7	1.86
July	54	37.7	1.43
August	43	40.5	1.06
September	60	39.7	1.51
October	73	43.1	1.70
November	69	43.7	1.58
December	85	42.5	2.00
January, '54	47	40.7	1.16
February	91	44.1	2.06
March	99	41.4	2.39
April	108	44.8	2.41
May	89	41.7	2.14
June	65	39.8	1.63
July	81	42.3	1.91
August	80	43.7	1.83
September	81	42.7	1.90
October	82	44.3	1.85
November	68	41.2	1.65
December	110	39.3	2.80

Revision of Control Charts: Another consideration in the use of control charts deals with changing the expected value to which the production quality is to be compared once the judgment is made that an assignable cause is probably present. If after a judgment is made the cause is isolated and corrected, there is no need to revise the control chart. On the other hand, if it is not isolated and corrected, succeeding judgments as to presence of additional assignable causes, over and above the already accepted presence of the one assignable cause, require a modification of the control chart to reflect the already established cause. Again, this problem (revision of control charts) is particularly important in accident application since, more often than not, it is very difficult first, to identify a new accident casualty and second, to know that it has been corrected.

As in the case of judging that action is indicated, there are no universally accepted criteria for revision of limits and each case must be given careful study. The nature of the accident statistic is such that particularly careful judgment should be made before limits are revised upward because this permits higher "no action" rates. Conversely, revision of limits downward might serve as an added stimulus and hence should be more readily performed. The following revision criteria listed by Grant can be considered:

1. Whenever 7 successive points on the control chart are on the same side of the standard.
2. Whenever in 11 successive points on the control chart, at least 10 are on the same side.

Example Demonstrates Technique

To demonstrate all the phases of the accident control chart technique the following example will be used. A control chart is to be set up to compare the monthly performance of a group of companies to the preceding industry average. The accident experience and exposure of the hypothetical companies is given in Figure 3.

Trial Limits: The basic period extends from January, 1953, through January, 1954, during which time there were 780 disabling injuries and a total exposure of 48,451,000 man hours.* The average rate $\bar{R}$ is:

$$\bar{R} = \frac{780}{485} = 1.61 \text{ Dis. Inj./100,000 man hours}$$

The action limits are computed for each month of the base period utilizing the same computed value of $\bar{R}$ for every period and the separate exposures for each period:

Month	Exposure Man Hours × 100,000	Action Limits
Jan. '53	25.4	$1.61 \pm 3\frac{\sqrt{1.61}}{\sqrt{25.4}} = 2.37 \& 0.85$
Feb. '53	26.6	$1.61 \pm 3\frac{\sqrt{1.61}}{\sqrt{26.6}} = 2.35 \& 0.87$
Mar. '53	32.7	$1.61 \pm 3\frac{\sqrt{1.61}}{\sqrt{32.7}} = 2.27 \& 0.94$

Since the actual rate of 2.45 for March, 1953, exceeds the upper trial action limit (2.27) for March, the trial limit procedure is repeated excluding the March data. The total number of disabling injuries in the base period is, then, 700 and the exposure is 45,181,000 man hours. The new trial average becomes:

$$\bar{R} = \frac{700}{452} = 1.55 \text{ Dis.Inj./100,000 man hours}$$

The action limits for each month are then computed with this new standard and, if all rates fall within their respective limits of this standard, the control chart is set up with this modified average as standard (Fig. 4).

Action Indication: The first indication that the rate might be unusually high is in February, 1954, when the rate of 2.06 fell in the warning range. The rates in March, April and May were clear indications that accident likelihood was unusually high in comparison with the average computed for the trial base period.

Revision of Limits: Revision of limits is suggested in August since the August rate was the seventh successive rate above the expected rate. The new limits are calculated by considering as the base period the preceding 13 months—August, 1953, through August, 1954—trial limits being computed in the same manner as previously outlined.

$$\bar{R} = \frac{990}{548} = 1.81$$

Month	Exposure Man Hours × 100,000	Action Limits
Aug. '53	40.5	$1.81 \pm 3\frac{\sqrt{1.81}}{\sqrt{40.5}} = 2.44 \text{ \& } 1.18$
Sept. '53	39.7	$1.81 \pm 3\frac{\sqrt{1.81}}{\sqrt{39.7}} = 2.45 \text{ \& } 1.17$
Oct. '53	43.1	$1.81 \pm 3\frac{\sqrt{1.81}}{\sqrt{43.7}} = 2.42 \text{ \& } 1.20$

It can be verified that the rates for August, 1953; January, 1954, and April, 1954, fall outside their action limits. The procedure therefore is repeated excluding the data for these months. We then have:

$$\bar{R} = \frac{792}{422} = 1.87$$

This value will be found to be satisfactory and, being plotted on the chart, is treated as the comparison standard for succeeding months.

**It should be noted that wherever amount of exposure is changing from one period to the next in a group of periods, the average rate for this group is computed by dividing the total number of accidents by the total exposure. It would not be strictly correct to average the individual period rates since this procedure would not weight the rates for their respective exposures.*

Figure 4
Accident Data Analysis for a Hypothetical Group of Companies

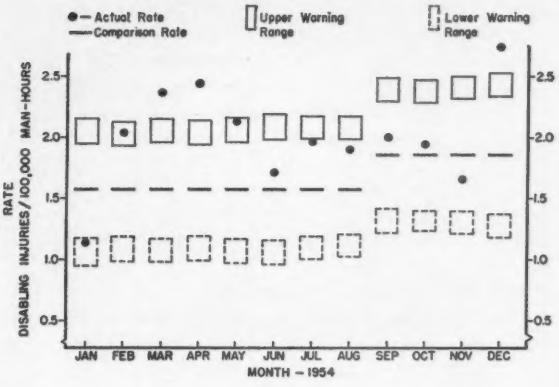


Figure 5
Computation of Ranges of Chance Fluctuation for Two Hypothetical Companies

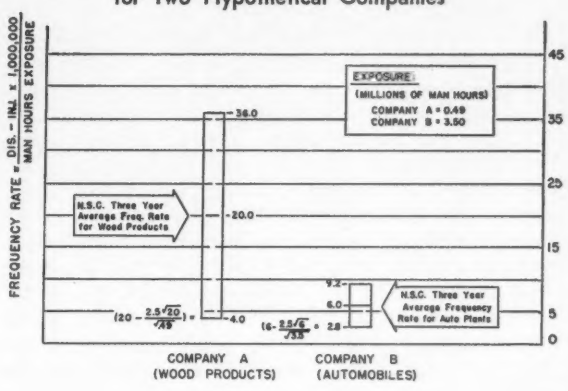
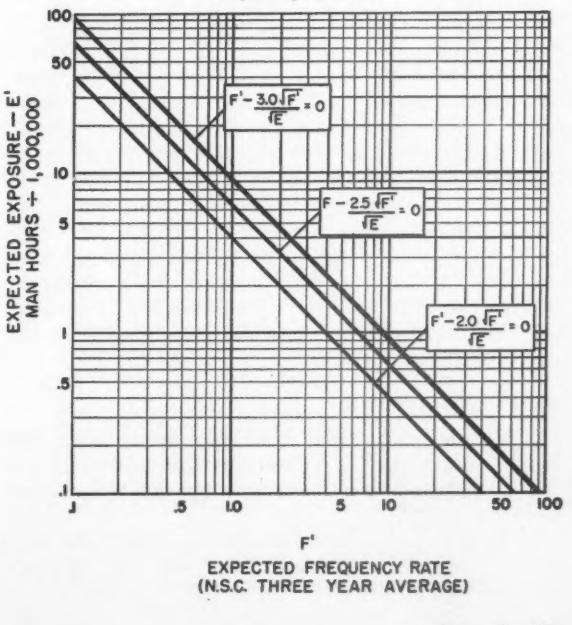


Figure 6
Critical Exposures as a Function of Expected Frequency Rate



Effect of Exposure and Interpretation

The behavior of accident rates with changing exposure has long been known by safety directors; the rates of small companies tend to fluctuate more widely than those of larger companies; smaller companies achieve zero frequency rates as well as extremely high frequency rates more frequently. This can be seen analytically from expression [2] in which the range of variation is inversely related to the square root of the amount of exposure. This is shown in Figure 5 where the accident control charts for two companies of widely differing exposure are plotted utilizing 2.5 sigma limits. The two companies will vary around their own appropriate standards but the range of variation of the large company B will be much smaller than that of the smaller A.

An interesting situation arises when the lower control limit (either warning or action) falls below zero; that is, is negative. Clearly a negative frequency is impossible. The only possible interpretation is that there was insufficient exposure to allow for meaningful interpretation of a zero frequency rate. The simplest way to get around this difficulty is to increase the length of the period under consideration to the point where there would be sufficient exposure to allow for meaningful interpretation of a zero rate. Thus, a two month index might be meaningfully analyzed while a one month index might be of little use.

To facilitate interpretation of zero frequency rates, the authors have prepared a chart, Figure 6, on which are plotted the minimum exposures required for interpreting zero frequency rates as a joint function of the standard and the exposure of the accident control chart techniques presented in this paper. The chart is entered from the bottom at the frequency rate appropriate for the company's type of operation, and from the left at the estimated exposure. If the intersection falls below the line, the company does not have sufficient exposure to allow for anything but a chance interpretation of a zero rate. Either the 2.0, 2.5 or 3.0 sigma line can be used depending on the decision function chosen.

Conclusions

The safety engineering profession is constantly confronted by the problem of having to decide whether or not there has been some change in accident likelihood. The usual statistical basis for this decision, until recent years, has been the accident rate. However, the profession should accept as fact that the accident rate is a statistic that will fluctuate even without any change in the underlying accident likelihood. Thus, it is clear that any meaningful interpretation of a rate must be made in relation to this fluctuation. Accident control charts represent an analytical tool for making such meaningful interpretations of accident rates. Therefore, if properly used, these charts can provide valuable guidance to the direction of the accident prevention effort.

Bibliography

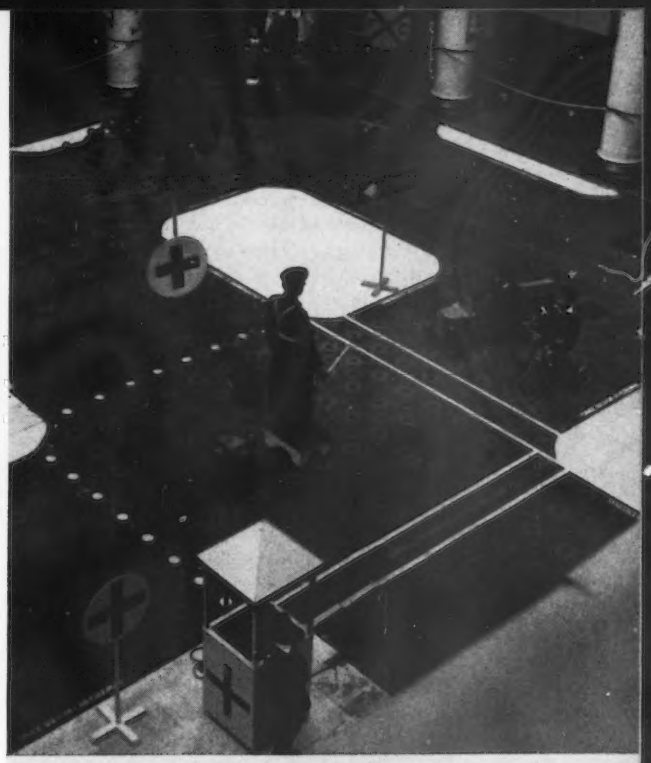
1. Goode, H. P., 1946. How, why, when, where and how many? A new approach to accident frequency rates. Safety Engineering, Vol. 92, July, pp. 25-26.
2. Howell, J. M., and Johnson, L., 1946. Statistical control of accidents. Iron Age, Vol. 158, July 18, pp. 56-57.
3. MacFarland, R. A., 1953. Human Factors in Air Transportation, pp. 521-4. New York: McGraw-Hill.
4. Mathewson, J. H., Brenner, R., and Hulbert, S. F., 1954. Analysis of mass air force motor vehicle accident data. Report 54-69, Department of Engineering, University of California, Los Angeles, August, 326 pp.
5. Norden, M., Orlansky, J., Jacobs, H., 1956. Applications of statistical quality control techniques to analysis of highway accident data. Highway Research Board Bulletin 117, National Research Council, Washington, D. C., January.
6. Lee, R. E., 1955. A statistical approach to control of accidents. Occupational Hazards, Vol. 18, No. 1, November, pp. 29-31, 38-42.
7. American Standards Association, 1942. Method of controlling quality during production. American War Standard, Z1.3-1942, 20 pp.
8. Grant, E. L., 1952. Statistical Quality Control. 557 pp. New York: Mc-Graw-Hill.
9. Burr, I. W., 1953. Engineering Statistics and Quality Control, 442 pp. New York: McGraw-Hill.
10. Greenshields, R. D., Shapiro, D., Ericksen, E. C., 1947. Traffic performance at urban intersections. Technical Report No. 1, Bureau of Highway Traffic, Yale University, New Haven, Conn.
11. Gerlough, D. L., 1955. The use of the Poisson distribution in problems of street and highway traffic. Eno Foundation Monograph, Poisson and Traffic, 58 pp.
12. Johnson, H. M., 1937. The detection of accident prone drivers. Proceedings, Highway Research Board, Washington, D. C., pp. 444-54.
13. Greenshields, B. D. and Weida, F. M., 1952. Statistics with applications to highway traffic analyses. Eno Foundation for Highway Traffic Control, Saugatuck, Conn., 238 pp.
14. Forbes, T. W., 1950. Statistical techniques in the field of traffic engineering and traffic research. Proceedings, 2nd Berkeley Symposium Math., Statistics, 1950, University of California Press, Berkeley, 1951, pp. 603-25.

The authors wish to express their appreciation to several persons who have assisted in the development of these concepts. The paper is a direct result of a highly active teaching and research program in industrial safety at the University of California that was initiated and has since been under the general direction of Dean L. M. K. Boelter, chairman of the Department of Engineering on the Los Angeles campus. Dean Boelter reviewed and commented on an earlier version of this paper. Professor George W. Brown, also of the University of California, has offered valuable suggestions on the statistical methodology. Colonel W. L. Tubbs (USAF, Ret.), the assistant for Ground Safety, Headquarters USAF, Washington, D. C., supplied Air Force accident data which was examined during the course of developing the ideas. J. H. McKenzie, manager of the Safety Department, General Petroleum Corporation, has examined the procedures and offered suggestions based upon his own experience. J. M. Kaplan, secretary of the Greater Los Angeles Chapter, National Safety Council, supplied data for testing the procedures. J. W. Stennett, manager of the Accident and Fire Prevention Department, National Association of Mutual Casualty Companies, reviewed an earlier version of the paper and offered valuable suggestions to simplify the presentation.

Many U. S. industries and organizations help our Latin neighbors develop safety programs. Our government also plays a major role in . . .

Safety Engineering Education in South America

by Morris B. Wallach



Learning by doing is applied to traffic safety for students at Chilean grammar school.

SURVEYS conducted in South America, including one by Dr. Milton Eisenhower, have disclosed the fact that no other part of the world is developing so rapidly as this area. Frequent requests for information and assistance expressed by South Americans have demonstrated their desire for greater production and higher living standards, not only in the future, but now.

Such requests have been received by the American Embassies, the International Cooperation Administration and other U.S. government agencies. Assistance of this type falls into the category of U.S. technical assistance to underdeveloped countries. The development of country-wide safety programs has become an important contribution within the scope of teaching our technical "know how," in the fields of productivity improvement and good labor-management relations, to foreign governmental, industrial and labor agencies. Safety education and training contribute an important part of a seven step planned program procedure which includes:

1. *Survey of Extent of Need for a Program.* At the request of the foreign government involved, a safety consultant is sent to the country for a short period to make an initial survey of need. The consultant decides at which level the program should start, based on the industrial development and general progress of labor and management productivity and the prevention of work accidents.
2. *Development of Disabling Injury Statistics.* Existing industrial accident and injury statistics are reviewed in order to determine their deficiencies, to recommend standards for the computation of disabling injury statistics and to develop a procedure for the analysis of such statistics to reveal the cost of accidents and injuries to labor and industry.
3. *Safety Engineering Education and Training Courses.* This includes two types of education, (a) in the U.S. Department of Labor, universities, etc., where trainees are sent from foreign countries to learn the theoretical and practical application of safety principles to production processes, and (b) the development of safety engineering courses within the foreign countries and universities, departments of labor, national insurance organizations, industrial associations and trade unions by U.S. safety consultants who are assigned to the particular foreign country for periods extending to two years or more. Such training is not only for the engineer, the supervisor and the worker, but also for the professor of the university, for the teacher in the primary schools and for instructors who in turn teach engineers, foremen, workmen and labor leaders.
4. *Program Development in Plants.* Upon request by an industrial plant or organization, a survey is made to determine the extent of need and the type of program to be developed. Then a detailed analysis of processes and operations is conducted in three or four separate visits of one full day each. At this time individual operations are studied to determine the

Morris B. Wallach, safety engineer with the Bureau of Labor Standards, for two years was industrial safety consultant in Chile for the U. S. Department of Labor. He is a member of the American Society of Safety Engineers.

efficiency of work procedures and to eliminate existing hazards from the operation. Recommendations are developed as a result of these studies. Further contacts are made with management and the union, at which time a safety organization is planned with labor-management participation. A report is then drawn up and submitted for consideration by management and the union. When agreement is reached the program is put into effect under the guidance of the U.S. consultant and the trained safety engineer or technician who is working with the consultant in the development of the program. The safety engineer or technician then follows up the program at regular intervals to determine its progress and to improve its efficiency.

5. *Labor-Management Cooperation.* With all these activities, labor and management are constantly working together in the plants in the operation of the safety program. Close coordination between the two groups is essential for the proper development and continued progress of the program.
6. *Development of a National Safety Council.* The logical outgrowth of a successful national program is a determination to organize a national safety council. The U.S. consultant encourages, advises and assists industry, labor, the public, educational organizations and safety engineers and technicians with the development and organization of a national safety council whose purpose is the advancement of safety in the fields of industry, education, traffic and the home, and to assist in the development of standards and laws in their respective fields.
7. *Development of Annual Safety Congresses.* In order to acquaint the general public with the activities of the national safety council, of the safety engineers and technicians and of professors teaching safety in the universities, a Safety Congress is planned and developed under the guidance of the national safety council of the country. An additional purpose for the Congress is to teach the general public some of the basic principles of accident prevention and how they can cooperate to assist with the general program.

Safety posters on display were developed by primary school children in Chile.

President of Chile (center) watches author (left) demonstrate training model for manual lifting procedure at First Safety Congress, Santiago, Chile, in October, 1953.

Two countries in Latin America have completed the above seven step program—Chile and Uruguay. Other countries such as Mexico, El Salvador and Brazil have training courses in industrial safety but have not completed the planned program to date.

Since the writer took part in the development and conduct of university courses and training courses in Chile, this country can serve as an example of what has been done, is being done and what can be done in the field of safety engineering education in South America.

In March, 1953, an Industrial Safety Engineering Training Course was set up and was sponsored by the U.S. Operation Mission to Chile in cooperation with the University of Chile. The course continued for one year, embraced the basic principles of industrial safety engineering as they applied to Chilean industry and contained progressively more advanced and specialized work, including teaching procedures and the development of training courses.

The 36 students registered for this course were practicing engineers, safety technicians and Department of Labor safety inspectors. Out of this first group we developed a staff of 10 safety engineering professors who are presently teaching in the Chilean universities. Some

Location	Students	No. of Students	Duration of Course
1) Catholic University, Santiago	Fifth year—industrial, civil, chemical, mechanical and electrical engineering students and commercial engineering students.	92 (3 groups)	Permanent required course for engineering students during their fifth year—2 hrs. per week.
2) Chilean Technical University, Santiago	Third year—industrial, mechanical and electrical engineering students.	43	Permanent required course for engineering students during their third year—1 hour per week.
3) Military Engineering Academy, Santiago	Military engineering students (officers).	15	Permanent required course for military engineering students—2 hours per week.
4) Caja de Accidentes del Trabajo	Engineers and technicians from industrial plants.	55 (2 groups)	9 months (150 hrs. of study).
5) Caja de Accidentes del Trabajo	Supervisors from industrial plants.	87 (4 groups)	2 months (30 hrs. of study).
6) Caja de Accidentes del Trabajo	Industrial labor union officials.	33	2 months (30 hrs. of study).
7) Union Headquarters, Industrial Copper Workers	Union members.	128 (4 groups)	2 months (30 hrs. of study).
8) Industrial School of Nuñoa	Machine Shop apprentices (part of apprenticeship training program in Chile; safety will be taught as a part of all future apprenticeship training courses).	30	3 weeks (6 hrs. of study).
9) Chilean Army Training Center	Sergeants—(group 1). Officers—(group 2). Automotive farm equipment (tractors, reapers, etc.).	36 8	Agricultural Safety Training Course, 2 months (30 hrs. of study).

are university staff professors and 15 are instructors in industrial safety fundamentals.

The instructors began to teach 30-hour courses for supervisors, workmen and union officials. Some of the courses were conducted within industrial plants in conjunction with the development of complete safety programs. Others were conducted in the Caja de Accidentes del Trabajo, a semi-fiscal insurance agency resembling somewhat our State Insurance Funds. These courses for supervisors and workmen were conducted after working hours and on a voluntary basis. The Department of Labor in Chile sponsored courses which were conducted by safety inspectors who were in the original group of students attending the year course.

One of the instructors was assigned the job of teaching 30-hour safety training courses for union officials and members in the labor union headquarters.

Training courses completed during 1954 are shown in the table above.

The writer left Chile in February, 1955, at the completion of a two-year program. Since then the country-wide program has continued to expand. Other Chilean universities—such as the University of Concepción, the Santa Maria Technical University of Valparaiso—have started industrial safety engineering courses. Plant training courses increased as new plant safety programs were developed and 30-hour safety courses were conducted at other union headquarters, the Caja de Accidentes del Trabajo and the Department of Labor in Chile. The entire seven step planned program is continuing successfully in Chile.

A similar program has been in effect in Uruguay since 1953. The U.S. safety technician left there at the completion of a two year program. Although the safety educational program was not introduced in universities as successfully as in Chile, still the program has continued in 1955 and has expanded under the guidance of the Department of Labor and Industry of Uruguay and the Banco de Seguros del Estado.

In addition to educational safety programs in the universities, associations, industries and labor unions, the primary schools have also introduced safety into their scholastic curriculum, not only in the field of traffic safety, but also home and school safety as well.

The Green Cross symbol of safety is growing in importance in the eyes of the South American people in the universities, schools, industry, on the streets and in the homes. Safety is making progress in South America.

AFTER EFFECTS OF NUCLEAR RADIATION

by Dr. Hermann J. Muller *

IN BOTH THE military and the peaceful utilization of nuclear energy the feature most damaging to human life, health and well-being is the escaping high energy radiation.

It was otherwise in the bombing of Hiroshima and Nagasaki. There many more people were killed by the collapse of buildings, by physical shock, fire and heat rays than by the high energy radiation. It must be admitted that the radiation deaths caused by these two bombings are in a sense still occurring, however, and that they will continue for several decades, if we classify in this way the excess of deaths per year among persons of any given age who had been exposed to the bombing, as compared with an equal number of persons of the same age who had not been exposed. But even if we add the great number of years of life lost in this way to those lost by the radiation deaths of the first few weeks, the total toll of deaths caused by radiation turns out to be smaller than the number killed by the blast effects. The same would hold in general for A-bombs used in a tactical way in warfare in the future, if these bombs are not purposely rigged, as with cobalt, or set off near the earth's surface so as to increase the fallout.

1. *Amount of Radiation Damage To Be Expected*

On the other hand, an H-bomb of the type set off in 1954 and 1955, although having an explosive force inordinately greater than that of an A-bomb, is capable through its fallout of destroying life by radiation damage over an area more than a hundred times as great as that devastated by the blast effects. This is because in such a bomb the hydrogen fusion, initiated by a primary fission reaction of active uranium or plutonium, is used, secondarily, to provoke further fission. This occurs in a casing of ordinary uranium, a substance not easily induced to undergo fission. It is the radioactive fission products from this added uranium that give the fallout by far the major part of its lethal potential. Because of the cheapness of the needed additives we may assume that in any future all-out-war—and what war can be guaranteed not to become all-out?—great numbers of these super-bombs will be available as strategic weapons. Since each such bomb can ravage thousands of square miles with its radioactive precipitation (8-12, 27), it is obvious that it can be highly effective even when it is far from accurately placed. *(Numbers in parentheses indicate references listed at end of article.)*

It is also obvious that, to enable these bombs to do the maximum damage to large populous regions, the attempt will be made to space them in such a way as to have their wide marginal areas of fallout overlapping one another. This is the procedure called "pattern bombing." In this way even the marginal areas are brought above the radiation level for lethality, and so the range of effective fallout for a given number of bombs is much greater than if they were either widely separated or superposed. At the same time, most of the survivors of such pattern bombing are caught in a position so interior within the group of conjoined fallout areas that they must endure a much longer period of hiding out in basements and underground shelters until their evacuation can be undertaken without their being subjected to too much radiation en route. For their trip to a relatively safe area will take such a long time that the level of radiation must fall to a much lower level than if their journey were a short and easy one. Eventual evacuation would of course be imperative for all these people, because for years it would be dangerous to live in such regions.

It would be surprising if the surviving population of a country that had been systematically subjected to pattern bombing did not accumulate in the course of time an average of a hundred to several hundred roentgen units* of radiation, even though they had been well disciplined for such an attack and well provided with underground shelters, radiation counters, facilities for decontamination, battery-powered radios and other essential supplies. At least, it has been estimated that people remaining all the time in the basements of suburban-type houses, well sealed off from the dust of the outer air, in positions 110 miles downwind from an explosion of the type set off in the Pacific in March two years ago, would receive some 100 roentgens of gamma radiation

**This article constitutes a revised edition of an address entitled "The Effects of Radiation on the Human Constitution," delivered before the Military-Industrial Conference, Chicago, Feb. 9, 1956. The first version was published in the* Saturday Review *on June 9, 1956.*

**A roentgen unit (written as "r") of X or gamma radiation is the amount that will, when applied to air under standard conditions, produce ions carrying 1 electrostatic unit of charge per cubic centimeter. The actual number of pairs of ions giving this result is about 2.1 X 10^9 per cc. In water or tissue, however, the number of pairs of ions produced by 1 r is about 800 times this. A chest X-ray commonly delivers about a tenth of a roentgen (.1 r) to the interior of the chest. The body as a whole, including the reproductive organs, usually receives some 4 to 5 r of radiation from natural sources in the course of a reproductive generation (30 years). Some 400 r to 500 r, if delivered in a short time (e.g., an hour or less), would kill about half of the persons exposed to it.*

from outside during the first week alone (9). Moreover, exposure outdoors in that region on the eighth day, if rain or artificial decontamination had not occurred, might deliver 80 roentgens more of whole body radiation to them in 24 hours. This would not be enough to give many of them serious radiation sickness if they did not get the dust on their skins or into their bodies.

If, however, the population was less well prepared and instructed than here assumed the survivors might in the course of the first week or two receive an average dose of well over a thousand roentgens. This is a dose several times that which would have killed them if it had been received all at once, and when received in this somewhat more diffuse form it would still be enough to give most of them pronounced radiation sickness. We shall not attempt to estimate here what proportion of the people in the entire fallout area would be less protected or at a shorter distance than this from the explosion and in consequence would have had such severe radiation sickness as to kill them. This proportion would depend very much upon how well the people had been disciplined in advance, provided with underground shelter, and otherwise equipped.

2. *Earlier Effects of Radiation*

There are still many gaps in our knowledge of the ways in which radiation produces the series of maladies known as radiation sickness, that afflict people within the first days and weeks after a heavy exposure (21, 24, 25). However, more and more evidence is accumulating that the chief basis of the disturbance lies in pointwise injury to the genetic material of individual cells, striking now here, now there, in a random fashion among cells that normally are replenishing themselves by cell division. Among the cells most actively engaged in such replenishment, and therefore very sensitive to killing by radiation, are those of the blood system, such as bone marrow and lymph gland cells. From these are derived the red and white blood cells and the little platelets necessary for insuring blood clotting. Intestinal lining cells must also replenish themselves actively by division and therefore are similarly sensitive. To a lesser extent the same is true of skin and hair cells. Therefore these tissues are among the most affected by radiation and the symptoms that follow are largely secondary effects of the destruction, or the prevention of normal division, of large numbers of cells of these kinds.

For example, if enough intestinal lining cells are destroyed or prevented from being replenished, gaps arise in the lining through which vitally needed fluid leaks out into the intestine, while destructive intestinal juices seep into the body spaces (26). At the same time, the diminution in number of white blood cells reduces the body's defenses against germs and the reduction of clotting power leads to hemorrhages through the perforations that may have been induced in blood vessel linings. The cells of the reproductive organs also are rapidly dividing cells; hence the reproductive organs are likely to enter a period of sterility.

Part of the effect, in all these cases, must be a consequence of the temporary checking of cell multiplication that radiation is known to cause. But much of it is a consequence of the breaking of the chromosomes within the cells. The chromosomes are the minute threads that contain the cell's hereditary equipment—its thousands of different, highly specialized genes. It is only when cells divide, and therewith transmit their precious cargo of genes to their two daughter cells, that a break in a chromosome, previously produced in it by radiation, may result in a cell that lacks one or more of the resulting chromosome fragments. Such a cell and all cells later descended from it are likely to be abnormal and impaired in functioning and may die off. A break may also be followed by a sticking together, at their raw ends, of chromosome pieces that do not belong together, and these combination fragments may become lodged between the two daughter cells that are forming, in such a way as to prevent their proper separation from one another in that as well as in any following cell divisions. The result in such a case also is the eventual death of all cells descended from the one in which the chromosome breakage occurred. Thus, much of radiation sickness is an expression of the damage inflicted on the hereditary (genetic) material of numerous cells lying scattered throughout those tissues in which there is normally an active process of renewal by cell division.

On this interpretation it is not surprising that, if the irradiation has not been too drastic, there will be enough normal cells remaining so that, by the multiplication of these, the depleted tissues can become restored to a considerable degree. The restoration is often incomplete, however, and diverse parts of the body are thereby left in a somewhat weakened condition, in which the necessary operations are carried on less effectively. Since the more rapidly multiplying the cells in the given tissue were, the greater the damage, it is evident that the younger the individual is when irradiated, the more he will be

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affected. This will express itself, among other things, in a checking of growth from which he will never fully recover. Moreover, those parts of him that were in a faster growing, more formative state at the time of exposure will be especially retarded and deranged. That is why even doses of 25 to 100 roentgens, if delivered to the young fetus, can give rise to permanent abnormalities. Among these is the condition of small head or microcephaly, resulting in defective intelligence, that was found in some of the children born at Hiroshima several months after the bombing.

3. Delayed Effects

One of the kinds of damage to body cells that is sometimes brought about by radiation is the conversion of a normal cell, probably by some kind of mutation in a gene, into a cell with the potentiality of later producing a malignant growth, either of blood cells, as in leukemia, or of some other type. These symptoms sometimes become evident only when conditions are appropriate for such growth to occur—often not until decades after the irradiation. Fortunately, the malignancies are induced in only a small minority of people by such doses as can be tolerated by the whole body. However, in cases in which only a small part of the body has been irradiated, a dose may have been received that is far higher than the whole body could have tolerated. Here the chance of a malignancy later developing is much greater.

More frequent among the late effects of irradiation of the whole body are the development of minute spots of opacity in the lenses of the eyes. These cataracts, seldom large enough to impair vision seriously, show where individual cells had been permanently damaged, very likely by breaks in their chromosomes. It is only because the lens is a transparent tissue that we can directly detect these points of injury in it. However, it may be inferred that the same kind of thing happens in all parts in which there are cells that can divide. This would explain what is by far the most serious of the long-term effects of radiation on the exposed person himself—the shortening of his span of life.

It is remarkable how few people, even among physicians, are yet aware of this insidious effect on life span and of the exact rules it follows. These rules, in preliminary form, were discovered some 10 or more years ago by Dr. R. D. Boche, then at the University of Rochester but shortly afterwards at the University of Chicago and now in California. He discovered these rules on going over data obtained by a number of investigators during the war, under the Manhattan District project, on the time of death of irradiated mammals of several different species (2, 3). The principles were further developed by G. A. Sacher, A. M. Brues (4), E. Lorenz, and others. The results have been so consistent that there is no reasonable doubt of the application of the same rules to man, especially in view of some confirmatory evidence from man. They lead to the conclusion that, for each roentgen unit of radiation received by the whole body at a given age, if delivered at a rate of not more than a few roentgens per day, there is on the average a loss of something like five days of life, perhaps as much as two weeks, depending somewhat upon the age. There is still uncertainty about the exact quantity and about its manner of dependence upon age, but not about the general principle. No one particular ailment is thereby induced in the exposed group of mice, rats, dogs or people; they are just made a trifle more susceptible to all causes of death, much as if they had been aged by a given amount.

Since the effect is simply proportional to the amount of radiation, so long as the rate of radiation per day is low, a dose of 200 roentgens, received in a dispersed manner over a considerable period, would cause a pseudo-aging of something like 1000 days. That is, death would on the average occur nearly three years earlier than if there had been no exposure. This proportionality of the effect to dose at low rates of delivery of the radiation is understandable if it has its basis in chromosome changes, for at low dose rates these chromosome effects also follow this rule, unlike most biological effects. If, however, the rate of delivery of the radiation is raised considerably, so that the 200 roentgens here in question are received in a period of hours, the frequency of permanent chromosome changes becomes disproportionately greater, and corresponding with this there will be a more extreme curtailment of the life span.

In view of all this, it is rather surprising to read that a given amount of radiation is entirely harmless, or such a statement as the final sentence in a feature article entitled "Fallout True Story" (23), which appeared in the November, 1955, issue of the Office of Naval Research's magazine, "Research Reviews." Referring to the 64 natives of the Island of Rongelap (Marshall Islands) who had received an estimated 175 roentgens of gamma radiation and additional radiation of a beta type, and who had shown some of the symptoms of radiation sickness, this article concludes: "Yet, after 18 months, all 64 of these natives are still alive, *and none suffer any lasting aftereffects as the result of their experience with radioactive dust.*" (Italics mine.) Do we not officially admit the long known shortening of life, and the fact that any exposure, no matter how small, exerts some permanent damage?

As for larger doses, it can be calculated that people of, say, 30 years of age who, having been in a bombed region, have somehow managed to survive 1000 roentgens (the first third of the dose received in the first day or two and the rest by the accumulation of decreasing amounts over a period of weeks or months), will probably succumb within something like a decade. Few of these deaths (except for some leukemias and other malignancies) will be individually traceable to the radiation, however. They will appear to have followed from "natural causes." Only a statistical comparison with the frequency of deaths among non-bombed populations will prove the falsity of this interpretation. A similar situation exists in Hiroshima today, but the increase in the death rate is much less extreme than in our hypothetical example because of the relatively small amount of fallout that that bombing produced.

4. Effects on the Descendants

It is fortunate that such large doses as 1000 r, if received gradually, usually cause sterility. For the sum

A 750

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total of hereditary damage done to later generations by a given amount of irradiation of persons who later reproduce, if expressed in terms of years of life lost, is very much greater than the damage done to the directly exposed individuals. In fact it is probably more than 10 times as great. This total damage to the descendants is spread out over so many generations, however, that even in the most affected generation, the immediate children, it would be very difficult to demonstrate the damage after a dose of about a hundred roentgens. Yet the damage is nonetheless very real and hits humanity at its innermost and most precious core (13-20).

This damage to later generations, unlike that causing the trouble in the tissues of the exposed individual's own body, does not have its basis mainly in gross fragmentation of the chromosomes. The view most widely accepted by geneticists is that such damage consists mainly of permanent chemical alterations, called *mutations*, that are produced by the radiation in a haphazard way in one or another of the genes, the hereditary particles lying within the chromosomes of the reproductive cells. Each chromosome may in fact be regarded as a chain of hundreds of genes, arranged single file. Each of the thousands of different genes in a reproductive cell will have its specialized role to play in the development and maintenance of the offspring which that cell, after fertilization, will produce, and will govern specific reactions in the intricate system of operations whereby that offspring will live and in its own turn reproduce. Thus any alteration of a single gene's composition, brought about by some minute collision that was induced blindly by a bolt of radiation, will in the vast majority of cases cause some disturbance or impairment in the development or functioning of the body derived from an affected germ cell.

It is an old wives' tale, repeated in science fiction, that mutations commonly take the form of monstrosities or freaks. It should be recognized that the impairment will usually be slight, or even unrecognizable, consisting of such traits as a slightly greater than average tendency to rheumatism, or to gastric ulcer or high blood pressure, often not evident until the later years of life, or a higher requirement for some vitamin or a slightly lowered I.Q. One reason for this lack of marked effects is that an offspring containing a mutant gene will almost always inherit from its other parent an undamaged gene of the original kind in question. This normal gene will usually exert a much stronger effect than the mutant gene, being, as we say, "dominant." Yet for all that the mutant gene, and the slight impairment caused by it, will tend to be inherited by a succession of generations. It will tend to hamper these descendants to some small degree at least, even in the presence of the normal gene, until in the end some heir to this legacy finds himself in circumstances where just that disability happens to become the deciding factor in causing his death before maturity or his failure to reproduce. Thus the mutant gene will at long last be eliminated from the population, but only at the cost of the dying out or biological frustration of some descendant, usually a remote one, and the hampering, in some degree, of legatees belonging to the intermediate generations.

In its impact on the population as a whole this kind of effect on later generations is in some ways curiously analogous to the shortening of life produced in the directly exposed generation. For the impairments appear natural and are lost in the crowd of otherwise existing dysfunctions. Yet they may take a very considerable toll. In any given case we can never be sure that the infirmity or the death was caused by the radiation.

It is better established for the mutations inherited by the offspring than for the shortening of the life span of the exposed individuals themselves, that the abundance of the effects is directly proportional to the dose received, no matter how large or small that dose. Thus there is no dose so small that it fails to entail its proportionate risk of causing a mutation. In the case of the mutations of genes, however, unlike the life span effects, the rate at which the radiation is received makes no difference. A given total dose is just as effective in producing these mutations if its delivery was dispersed over a period of 30 years as if it was concentrated into two seconds. Thus the total number of mutations produced by radiation in one generation depends on the total dose of radiation accumulated between the conceptions that gave rise to that generation and the conceptions that give rise to the following generation.

How many mutations are produced in man by a given dose is a matter of considerable uncertainty. However, in the light of data from other animals, the most probable value is that each roentgen unit received by one parent results in one induced mutation among about 400 of his germ cells. This means, for example, that if a parent had received 100 roentgens any child of his conceived after that time would have one chance in four of receiving an induced mutation from him. That is, there would be one such mutation among every four of his children, in addition of course to the several or many mutations of natural origin that they would also be inheriting, mostly from the remote past, and that had not yet been eliminated. If both parents had received 200 roentgens, thus having a total of 400, each child, on the average, would inherit one induced mutation.

It is readily seen that even though each person of the next generation contained, on the average, one mutation induced by the radiation, this would still be far from enough to threaten seriously the continuance of the population as a whole. For we all have a fair number of mutations already and are able to stand them. Therefore mankind would not be wiped out by this means, although of course it could be wiped out in a much more direct way by nuclear warfare if the leaders of mankind became insane enough. Nevertheless, short of such an ultimate catastrophe, any such tampering with our biological birthright as nuclear war would bring is not to be viewed with equanimity. This is especially the case in view of the fact that the conditions of living which in the past led to the elimination of those lines of descent that were more heavily burdened with impairments are no longer exerting a strong enough influence of this kind to prevent the population from deteriorating in some important respects. Thus, whatever genetic damage may be done by radiation today or tomorrow would tend to persist for many more centuries than it would have formerly, and some of it would probably increase. For these reasons, even though the genetic damage entailed

by nuclear warfare would by no means be insupportable, provided this warfare were not repeated in future generations, yet our descendants would suffer to no small degree, and would place the blame on our shoulders, if we did not take all possible steps to avoid this source of biological contamination.

5. Measures for Defending Our Genetic Heritage

There are some indications, especially from Dr. Hollaender's group at Oak Ridge, that methods of therapy or prophylaxis may eventually be developed which, if applied shortly before or even immediately after exposure, will drastically reduce radiation damage, perhaps by as much as 50 per cent (5-7). In bacteria this can be done even in the case of the mutation-producing effect. There is little indication, however, that harmless, practicable methods of this kind can be made available for man on a broad scale in the near future, especially for radiation occurring at an unpredictable time or over an extended period, nor do we yet know whether these methods would work against the production of mutations in man. But even if they worked fairly well they might, by saving for life and reproduction large numbers of persons who otherwise would have died from overexposure, open the way for the transmission to later generations of as many induced mutations that otherwise would have met extinction, as the number of mutations that they prevented from occurring. Thus, in addition to such measures, we should also prepare to use other, simpler but less thoroughgoing ones.

In this connection it should again be emphasized that the effect on later generations is produced only by the exposure of people who will later reproduce. One of the measures, then, if war seems imminent, is to evacuate to the country as many children and young people as possible, and also pregnant women and mothers with infants. This is a procedure similar to that which was successfully carried out on a large scale in England during World War II in order to avoid the blast effects of chemical bombs. In this case they must be evacuated to regions hundreds of miles downwind, with respect especially to winds of the upper air, from major cities and strategic points. This very cumbersome procedure, however, even if executed satisfactorily, will not save the genes of the young men, or of many of the young women.

The other major measure for defending our genetic heritage is to take into account in our plans for civil defense and rehabilitation following bombings the very particular need to protect from exposure the reproductive cells of our youth. Let people under 35, and all who are likely later to reproduce, be the last to be accepted for use after a bombing has occurred, in such essential services as rescue work, decontamination, bringing in supplies, transportation and everything else that requires activities that are carried on in relatively unsheltered situations. In this way the older generation may be better assured that, whatever else has happened, their descendants will not be subjected to a lasting biological incubus imposed by negligence of which they, the forebears, had been guilty.

6. Remote Fallout Damage

This discussion so far has been confined to the effects on the human hereditary constitution exerted in the region of an actual nuclear attack, or at least in the region of the "local" fallout from such an attack. Much of the fallout from hydrogen bombs, travelling high in the stratosphere, would be dispersed throughout the world and be precipitated for years. However, it can be calculated that even if the equivalent of seven hundred 15-megaton bombs, each of the type and order of strength of that at Bikini on March 1, 1954, were released, the fallout in remote regions would raise the amount of radiation received by the population in the world at large, outside of the local fallout areas, by only one to a few times the amount they ordinarily receive from natural causes (9, 10, 27). This damage, *if not repeated* by similar warfare in later generations, could not seriously impair the genetic composition of the population as a whole, even though it would be harmful to many widely scattered, untraceable *individuals*.

Much more radiation would, however, be received if large amounts of cobalt or certain other substances had been purposely added to the bombs or had been in range of the fire-ball, or if materials, such as fish, derived from the areas of heavy fallout were used as food. Moreover, it is by no means established as yet that certain long-lived radioactive isotopes, such as those of strontium and cesium (9-12, 20), would not accumulate in particular tissues, such as bones, to a degree which would give rise to grave disorders, including cancers, in the population of the directly exposed generation.

7. Protection in the Peacetime Use of Nuclear Energy

When we turn from these military effects to the peacetime utilization of nuclear energy, we find a curious situation. At Oak Ridge and presumably at some of the other government-sponsored atomic installations, the officially recognized "permissible dose" of .3 roentgen per week is set (1, 22). In actuality, however, relatively few workers receive more than a fifth of this amount. In the course of five years, a good average of the time the employes usually stay at such a plant, a more exposed worker might thereby receive about fifteen roentgens. This would not result in children who were conceived by him during or after that time receiving an alarming number of mutations caused by the radiation. Moreover, it would result in an average shortening of the worker's own life span by only a few months.

Since, however, it is expensive to provide remote control mechanisms, waste disposal and shielding for protecting the worker to such an extent as at Oak Ridge, we can hardly expect industrial plants now planning their installations and procedures to keep down the dose much below that designated as permissible. This consideration would be even stronger in the case of government-sponsored plants of some countries under greater economic stress than our own. Moreover, it is to be expected that as conditions of employment in such plants become stabilized the workers will remain longer and that, since many of them are highly trained, the plants will attempt to keep them. Consider now what an exposure of "only" the official .3 roentgen per week will

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amount to in the 40 years from age 20 to 60. It will come to 600 roentgens—more than that of most exposed survivors in a nuclear war—and in the first 10 years, perhaps prior to the worker's reproduction, it will be 150 roentgens. This amount before reproduction, on the part of just one member of each married couple, presumably the father, will probably cause at least one in every 2 or 3 children, on the average, to receive one mutation induced by the radiation. This is a frequency several times as high as the new mutations that would appear among these children from all natural causes. The induced mutation would thereupon tend to go on down to hamper a long line of descendants until at last it extinguished that line.

Because mutations are usually unspectacular and unidentifiable it is not likely that this visiting of the parents' transgressions on mostly remote descendants would, human nature and its present attitudes being what they are, cause a great deal of compunction on the part of the progenitors themselves. Not so, however, when they come to consider the effect of the 600 roentgens accumulated throughout life on their own well-being. For the effect amounts to a shortening of life that may be estimated at something between 4 and 8 years. That is, the worker's life is shortened by something like one or two years for every 10 years that he works at such a plant. Since this secret is at last creeping out of the technical publications it will not be long before the worker knows this. If industry would lower its so-called "permissible dose" by 9/10, to an average of .03 roentgens per week or 1.5 roentgens per year—an expensive but perfectly feasible undertaking—all but a small part of this damage would be avoided and, more important in the long run, future generations would be spared even more damage than the present one.

The cost of the arrangements necessary for this very high degree of protection has been estimated at some $100 per man per year, or $4000 for each man for 40 years (Manov, *Proceedings of the International Conference on Peaceful Uses of Atomic Energy*, Geneva, 1955). However, even if this hastily made and sketchy estimate of cost turns out to be several times too low, as it well may, the expense would not be as great as paying damages for the loss of 4 to 8 years of each worker's life, or for the higher wages they would demand in place of damages. Moreover, such arrangements if once attempted always undergo considerable reduction in cost in the course of experience and invention.

A plan which would ultimately be amply satisfactory and much less expensive is not to impose weekly ceilings of radiation at all, but to keep track of the exposure being accumulated by each worker and to see to it that he does not receive more than a given total amount of radiation over a given number of *years*. Thus, in the recent report of the Genetics Committee, set up by the National Academy of Sciences, in its study of the biological effects of atomic radiation (21), it is recommended that a worker in an atomic installation not be allowed to receive a total of more than 50 roentgens up to age 30 (by which time a man has usually conceived more than half of his children), nor more than another 50 roentgens up to age 40. It is also recommended that, wherever possible, older workers and those not likely to reproduce thereafter, be used for jobs subject to exposures higher than the ordinary ones.

It would be shortsighted and pernicious to wait for several decades until the untimely deaths of workers could be demonstrated statistically. The designing and setting up of atomic equipment and procedures which is now taking place should be guided by the most advanced knowledge we *now* have. Otherwise we shall be confronted with the far more expensive process of reconstructing our installations and economies later.

Concluding Comments

Only by frankly facing and adequately coping with the hazards of radiation can we satisfactorily maintain and enhance the morale of our workers and win their wholehearted support for a vast program of nuclear development. Growth of the utilization of nuclear energy on an enormous scale and along salutary lines is a vital necessity not only for the building up of our country's defensive strength; it is also necessary if we are to enter upon that unparalleled period of industrial expansion which will show the way for the bringing of well being to all the world. These are the tactics which will tend to ease those stresses of poverty, jealousy, ignorance and tyranny that among the unhappy and credulous millions of many lands less fortunate than ours are providing the preconditions for war.

We may justly be proud that it was our own country which at Geneva last summer took the lead in opening up this realistic course of action, a course which may finally lead civilization out of the critical situation now threatening its existence. But we must see to it that this good beginning is vigorously and wisely followed up. For it will not be many years before the power to commit disastrous acts of nuclear aggression has become distributed among many relatively undeveloped or small countries, the governments of some of which may be insufficiently responsible. The possibility may arise of a much less stable balance than that between two major powers. It will then be a cardinal necessity for people everywhere to come to understand that their conditions of life may be radically improved through the peaceful application of nuclear energy and that, on the other hand, its destructive application constitutes an invitation to universal catastrophe. The appreciation of this two-fold truth can be attained, however, only if the peaceful development is being conducted soundly. This means that its operations must be carried on with such rigorous safeguards that those working on the projects will feel no fear for themselves or their descendants and, in the absence of any such apprehensions, will take pride in the realization that they are among the foremost contributors to human betterment.

At the same time, the population in general must be sufficiently protected from genetic damage by the enforcement of a low enough ceiling of radiation from all artificial sources combined. This means effective supervision over medical as well as over industrial and military uses of radiation and over the disposal of atomic wastes. In setting this ceiling, it must be borne in mind that only one roentgen, delivered to each of a hundred million people, will do a hundred times as much damage to posterity, via the production of mutations, as a hundred roentgens, delivered to each of ten thousand people. Moreover, this genetic damage accumulates from generation to generation if the exposures are repeated in suc-

ceeding generations as the peacetime exposures are expected to be.

In view of these considerations the Genetics Committee in its recent report (21) recommends that close watch and control be kept over the total radiation being received by the population as a whole, with records of each person's exposures. The total dose accumulated by the reproductive organs in 30 years from all man made sources, it is recommended, shall not exceed 10 roentgens per person, on the average, but an effort should be made to keep it as far below this as possible. Further study should be instituted with a view to later revision of this figure, since present knowledge of the details necessary for a decision has been far from satisfactory. At present the American people seem to be receiving an average of about 3 of this "permitted" 10 roentgens from medical sources and a far smaller amount from fallouts and from the use of atomic energy. The medical exposures to the reproductive organs can unquestionably be decreased greatly by the use of relatively simple precautions, without impairment of medical diagnosis or treatments. But as atomic energy comes to be used to an ever greater extent, this will probably become a much more abundant source of exposure than that due to medicine unless the most rigorous measures for disposal of atomic wastes and for shielding against escaping radiation are instituted.

The boons that atomic energy offers mankind appear almost miraculous. But it will not profit us to gain any number of new worlds, if in the process of doing so we lose the best in our own natures.

References

1. Belcher, E. H., 1955. Protection against ionizing radiations. Nature, *176*: 375-376.
2. Boche, R. D., 1946. Observations on populations of animals exposed to chronic roentgen radiation. Manhattan Dist. Declass. Commun. 204.
3. —— 1948. On permissible exposure to radiation. Address at Symposium on Low Level Irradiation at Argonne Nat. Lab., Chicago, October 19. (Unpub.)
4. Brues, A. M. and Sacher, G. A., 1952. Analysis of mammalian radiation injury and lethality. Symp. on Radiobiology, J. J. Nickson, ed. John Wiley and Sons Inc., N.Y., pp. 441-465.
5. Hollaender, A., 1955. Modification of radiation response. Bull. Atom. Scientists *12*: 76-80 and Proc. Internat. Conf. Peaceful Uses Atomic Energy, Geneva, 1955, *16*: 106-113 (publ. 1956).
6. Hollaender, A., Baker, W. K., and Anderson, E. H., 1952. Effect of oxygen tension and certain chemicals on the X-ray sensitivity of mutation production and survival. Cold Spring Harbor Symp. Quant. Biol., *16*: 315-326.
7. Hollaender, A., and Stapleton, G. E., 1956. Studies on protection by treatment before and after exposure to X- and gamma-radiation. Proc. Internat. Conf. Peaceful Uses Atomic Energy, Geneva, 1955, *11*: 310-314.
8. Lapp, R. E., 1955a. Fall-out and candor. Bull. Atom. Scientists, *11*: 170, 200.
9. —— 1955b. Radioactive fall-out III. Bull. Atom. Scientists, *11*: 206-209, 230.
10. —— 1955c. Global fall-out. Bull. Atom Scientists, *11*: 339-343.
11. Libby, W. F., 1955. Radioactive fallout. Paper delivered at Alumni Reunion, Univ. of Chicago, June 3, 1955. (Mimeog. by A.E.C.)
12. —— 1956. The radioactive fallout and radioactive strontium. Paper delivered at Northwestern Univ., Evanston, Ill., Jan. 19, 1956. (Mimeog. by A.E.C.)
13. Muller, H. J., 1949. Is radiation a menace to posterity? Sci. News Let. *55*: 374, 379-380 (under editor's title, "The menace of radiation").
14. —— 1950. Radiation damage to the genetic material. Amer. Scientist, *38:* 35-59, 126, 399-425.
15. —— 1950. Some present problems in the genetic effects of radiation. J. Cell. & Comp. Physiol. *35* (Suppl. 1): 9-70.
16. —— 1954a. The nature of the genetic effects produced by radiation. Chap. 7, pp. 351-473. Radiation Biology, Vol. *1*, ed. A. Hollaender. New York: McGraw-Hill.
17. —— 1954b. The manner of production of mutations by radiation. Chap. 8, pp. 475-626. Radiation Biology, Vol. *1*, ed. A. Hollaender. New York: McGraw-Hill.
18. —— 1955a. Genetic damage produced by radiation. Science, *121*: 837-840.
19. —— 1955b. Radiation and human mutation. Scientific Amer., *193:* 58-68.
20. —— 1955c. How radiation changes the genetic constitution. Bull Atom. Scientists, *11*: 329-339 and Proc. Internat. Conf. Peaceful Uses Atomic Energy, Geneva, 1955, *11*: 387-399 (publ. 1956).
21. National Academy of Sciences, 1956. The biological effects of atomic radiation. Summary reports. 108 pp. A report to the public. 40 pp. (Genetic Committee report and report to the public reprinted in full in New York Times June 13, 1956.)
22. National Bureau of Standards, 1954. Permissible dose from external sources of ionizing radiation. Handbook *59*, issued by the U.S. Dept. of Commerce.
23. Office of Naval Research, 1955. Fallout true story. Research Reviews, Nov., pp. 1-9.
24. Patt, Harvey M., and Brues, Austin M., 1954a. The pathological physiology of radiation injury in the mammal. I. Physical and biological factors in radiation action. Chap. 14, pp. 919-958. Radiation Biology, Vol. *1*, ed. A. Hollaender. New York: McGraw-Hill.
25. —— 1954b. The pathological physiology of radiation injury in the mammal. II. Specific aspects of the physiology of radiation injury. Chap. 15, pp. 959-1028. Radiation Biology, Vol. *1*, ed. A. Hollaender. New York: McGraw-Hill.
26. Quastler, H. 1956. Modes of acute radiation death. Proc. Internat. Conf. Peaceful Uses Atomic Energy, Geneva, 1955, *11*: 121-124.
27. Rotblat, J., 1955. The hydrogen-uranium bomb. Bull Atom. Scientists, *11*: 171-172, 177.

Canons of Ethics for Engineers

Foreword

Honesty, justice and courtesy form a moral philosophy which, associated with mutual interest among men, constitutes the foundation of ethics. The engineer should recognize such a standard, not in passive observance, but as a set of dynamic principles guiding his conduct and way of life. It is his duty to practice his profession according to these Canons of Ethics.

As the keystone of professional conduct is integrity, the engineer will discharge his duties with fidelity to the public, his employers and clients, and with fairness and impartiality to all. It is his duty to interest himself in public welfare and to be ready to apply his special knowledge for the benefit of mankind. He should uphold the honor and dignity of his profession and also avoid association with any enterprise of questionable character. In his dealings with fellow engineers he should be fair and tolerant.

Professional Life

Sec. 1. The engineer will cooperate in extending the effectiveness of the engineering profession by interchanging information and experience with other engineers and students and by contributing to the work of engineering societies, schools and the scientific and engineering press.

Sec. 2. He will not advertise his work or merit in a self-laudatory manner and he will avoid all conduct or practice likely to discredit or do injury to the dignity and honor of his profession.

Relations with the Public

Sec. 3. The engineer will endeavor to extend public knowledge of engineering and will discourage the spreading of untrue, unfair and exaggerated statements regarding engineering.

Sec. 4. He will have due regard for the safety of life and health of the public and employes who may be affected by the work for which he is responsible.

Sec. 5. He will express an opinion only when it is founded on adequate knowledge and honest conviction while he is serving as a witness before a court, commission or other tribunal.

Sec. 6. He will not issue *ex parte* statements, criticisms or arguments on matters connected with public policy which are inspired or paid for by private interests unless he indicates on whose behalf he is making the statement.

Sec. 7. He will refrain from expressing publicly an opinion on an engineering subject unless he is informed as to the facts relating thereto.

Relations with Clients and Employers

Sec. 8. The engineer will act in professional matters for each client or employer as a faithful agent or trustee.

Sec. 9. He will act with fairness and justice between his client or employer and the contractor when dealing with contracts.

Sec. 10. He will make his status clear to his client or employer before undertaking an engagement if he may be called upon to decide on the use of inventions, apparatus or any other thing in which he may have a financial interest.

Sec. 11. He will guard against conditions that are dangerous or threatening to life, limb or property on work for which he is responsible or, if he is not responsible, will promptly call such conditions to the attention of those who are responsible.

Sec. 12. He will present clearly the consequences to be expected from deviations proposed if his engineering judgment is overruled by nontechnical authority in cases where he is responsible for the technical adequacy of engineering work.

Sec. 13. He will engage or advise his client or employer to engage, and he will cooperate with, other experts and specialists whenever the client's or employer's interests are best served by such service.

Sec. 14. He will disclose no information concerning the business affairs or technical processes of clients or employers without their consent.

Sec. 15. He will not accept compensation, financial or otherwise, from more than one interested party for the same service or for services pertaining to the same work without the consent of all interested parties.

Sec. 16. He will not accept commissions or allowances, directly or indirectly, from contractors or other parties dealing with his client or employer in connection with work for which he is responsible.

Sec. 17. He will not be financially interested in the bids as or of a contractor on competitive work for which he is employed as an engineer unless he has the consent of his client or employer.

Sec. 18. He will promptly disclose to his client or employer any interest in a business which may compete with or affect the business of his client or employer. He will not allow an interest in any business to affect his decision regarding engineering work for which he is employed or which he may be called upon to perform.

Relations with Engineers

Sec. 19. The engineer will endeavor to protect the engineering profession collectively and individually from misrepresentation and misunderstanding.

Sec. 20. He will take care that credit for engineering work is given to those to whom credit is properly due.

Sec. 21. He will uphold the principle of appropriate and adequate compensation for those engaged in engineering work, including those in subordinate capacities, as being in the public interest and maintaining the standards of the profession.

Sec. 22. He will endeavor to provide opportunity for the professional development and advancement of engineers in his employ.

Sec. 23. He will not directly or indirectly injure the professional reputation, prospects or practice of another engineer. However, if he considers that an engineer is guilty of unethical, illegal or unfair practice, he will present the information to the proper authority for action.

Sec. 24. He will exercise due restraint in criticizing another engineer's work in public, recognizing the fact that the engineering societies and the engineering press provide the proper forum for technical discussions and criticism.

Sec. 25. He will not try to supplant another engineer in a particular employment after becoming aware that definite steps have been taken toward the other's employment.

Sec. 26. He will not compete with another engineer on the basis of charges for work by underbidding through reducing his normal fees after having been informed of the charges named by the other.

Sec. 27. He will not use the advantage of a salaried position to compete unfairly with another engineer.

Sec. 28. He will not become associated in responsibility for work with engineers who do not conform to ethical practices.

Prepared by
Engineers' Council for Professional Development
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AMERICAN SOCIETY OF SAFETY ENGINEERS

Membership Information

THE American Society of Safety Engineers has established the following classifications of active membership:

MEMBER—To be eligible as a Member an applicant shall be at least thirty years of age and shall be engaged in safety engineering. In addition, he shall have either an engineering or science degree in an accredited college curriculum and the equivalent of eight full years' experience in safety engineering; or he shall have had the equivalent of ten full years' experience in safety engineering.

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